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Viscous elastic coating (VEC's): how they are unique and different from conventional corrosion prevention coatings.

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ABSTRACT

Viscous elastic coatings (VEC's) easily overcome many of the common issues that cause traditional coating to fail. VEC's offer immediate adhesion without the need for primer, require minimal surface preparation and form a homologue, continuous, self-healing protective layer. The materials bond at an intimate level and create a waterproof, impermeable coating that can operate in a wide temperature range.

Viscous elastic chemistry is unique and designed such that the viscous component gives it permanent wetting characteristics. This forces the material to flow into the pores and anomalies of a substrate. The elastic component of the product gives it the strength and feeling of a solid. VEC's always remain in a semi-solid state, provide high impact strength and allow for sufficient resistance against shearing. Ease of application and outstanding performance are what make VEC's an excellent technology for corrosion prevention. These products excel in offering corrosion protection for pipelines on areas such as soil to air transitions, flanges, casing, girth welds, field repairs, water proofing of casing end seals and vaults in addition to having numerous other applications.

Key words: viscous elastic, coatings, adhesion, corrosion

INTRODUCTION

Corrosion occurs on pipelines because coatings, in practice, can fail. This failure strongly depends on the type of coating, the soil conditions (environmental aspect) and, in case of rehabilitation, the circumstances under which a pipeline coating was rehabilitated on site. In practice, the application circumstances and surface preparation appear to be a critical part for proper long lasting performance of a coating. Experience tells us that many coating failures and especially rehabilitated coating failures are caused by failures during application and improper surface preparation.

Even though VEC's have been developed in the past 20 years, the basic principle is not new: wax and petrolatum tapes are viscous in nature. Older bituminous coatings show viscous elastic properties(1) when the temperature rises above their glass transition point. These coatings have shown good resistance in wet environments and when the environmental circumstances are stable, a reasonable life cycle. Furthermore, above its glass transition point, shielding effects are uncommon for these coatings. The basic principle of adhesion by van der Waals forces seems to be the common factor. VEC's are different due to their synthetic nature, a low glass transition temperature, a wide temperature range, constant wetting and an amorphous state. This paper will describe how VEC's overcomes many of the obstacles that can contribute to the failure of conventional corrosion prevention coatings. Most of the topics discussed in this paper are related to pipeline coatings.

Corrosion causes billions of dollars worth of damage every year. Pipeline sections sometimes have to be taken out of operation and often-large sections may need to be replaced due to serious corrosion damage. New coatings commonly must be applied in the field to prevent further corrosion of existing substrates and to protect newly installed pipelines.

VEC's have been developed for the protection of underground and above ground substrates against corrosion. A good application of a corrosion preventative coating determines the long-term effectiveness of a coating. In the marketplace there was a need for a coating that can be applied in the field with an easy and faultless application. VEC's have been specifically developed to do so by rheological behavior. VEC's show a clear viscous and elastic component (the reason behind the name VEC's). The viscous component is responsible for immediate adhesion, continuous wetting and conforming to the anomalies of the substrate.

The elastic component is responsible for structural strength, a wider temperature range and sufficient impact strength. VEC's show self-healing properties in case of small damages.

Conventional coating types, selection criteria and obstacles

In order to prevent corrosion, one can protect the bare substrate with a coating. Numerous coating types are available but one can roughly distinguish between the following types:

Factory coatings

- FBE, PE, PP Urethanes, etc.

Field applied coatings

- Spray coatings such as epoxy, urethane and zinc.
- Wax and Petrolatum based tapes.
- Bitumen-based coatings, coal tar enamel.
- Single or multiple layer PE/butyl tapes.
- Heat shrink sleeves

Coating selection. The selection of the coating depends on different factors such as:

- Estimated lifetime of substrate.
- Environment.
- Nature of the substrate (material, shape, position).
- Cost per square foot (coating material and application).
- Costs of repairs.

Important phenomena that can lead to coating failures. There are numerous issues that should be taken into consideration when discussing pipeline coatings, their application and the corrosion process. Some of these phenomena are:

a) Salts and osmosis
b) Adhesion
c) Microbiological induced corrosion (MIC)
d) Surface preparation
e) Water permeability

Coating obstacles versus VEC's

a) Salts and osmosis problems. The presence of salt, for instance NaCl dissolved in water, plays an important role in a corrosion mechanism:

$NaCl \rightarrow Na^+$ (natrium ion) + Cl^- (chloride ion) Fe^{3+} (iron ion) + $3\ Cl^-$ (chloride ion) $\rightarrow FeCl_3$ (iron chloride)
$FeCl_3 + 3H_2O$ (water) $\rightarrow Fe(OH)_3$ (iron hydroxide) and $3\ HCL$ (chloride acid)

This chloride acid accelerates the process in which iron electrons are lost:

$Na^{+} + e^{-} \rightarrow Na$
$2Na + 2H_2O \rightarrow 2NaOH + H_2$ (hydrogen)
$NaOH + HCL \rightarrow NaCL + H_2O$

Salt particles are often present on the substrate and are difficult to remove. Even rinsing a blasted pipeline coating with clean water will not remove the salt particles and contamination in the voids of the blasted pipe. As salts attract water and many pipeline coatings are not 100% water vapor or water impermeable, the presence of salt is always a risk in practice.

In the presence of salt, osmosis occurs. Osmosis can be described as a physical phenomenon that exists in the presence of a semi- permeable wall, better described as a selective filter. This wall will allow the solvent of a solution to penetrate but keeps the solved substance out. The wall is a barrier between two chambers whereby there is a difference in concentration of dissolved substance.

When the concentration of dissolved substance is lower in chamber A than in B, the solvent will now move to chamber B. This process will continue until the concentration levels of the dissolved substance of chamber A and B are equal. If one starts at the same volume level in the two chambers, the volume in A will drop but will rise in space B. This osmotic behavior will results in a pressure difference, sometimes creating so much pressure that a coating may blister or disbond. Osmosis is a well known phenomenon and a problem for coatings exposed to water where water-soluble substances are present under the coating on the substrate.

Therefore, layers of coating should have very low water vapor permeability. Many coating systems, no matter how well they have been applied, do not meet this requirement. One may think of systems based on polyurethanes, epoxies or unsaturated polyester resins.

The presence of salt particles on a substrate is not a problem if the coating is impermeable to water and the coating has an intimate contact with the substrate. Furthermore when a system is amorphous and in a semi solid state, the salt particles are embodied in the coating. As a result of such impermeability and intimate contact with he surface, osmosis will not occur and the embodiment of salt particles in the coating ensures that they are no longer present on the substrate.
Viscous-Elastic Coatings are impermeable to water(2) and therefore the hazardous salt particle is neutralized, as water will not travel through the coating. Rinsing with clean water in remote areas is no longer necessary and the risk of application failure is reduced to almost 0%. Extensive tests in this respect have been performed.

The use of VEC's will eliminate the occurrence of osmosis:

- VEC's are impermeable to water.

- VEC's bond to the surface through van der waals forces, with a distance between the substrate and the coating of around 10^{-10} m
- VEC's are a-polar, i.e., it is water repellent.
- The extremely good adhesion of VEC's and their 'wetting' characteristics prevent pressure build-up and the coating from disbonding. In addition, VEC's have self-healing characteristics. Minor pinholes are dealt with by the flow-under-pressure properties and damages will heal automatically.

b) Adhesion problems. Any pipeline coating must have good adhesion to the substrate. Coatings with no adhesion fail automatically. To obtain good adhesion in practice is not easy. The reason for this is that the application circumstances must be taken into consideration and that many coatings require perfect surface preparation. In addition, the difference between surface tension of the two different materials (substrate surface and coating material) can play an important factor in adhesion failures.

There are several forms of adhesion, as explained in the next paragraph. Coatings applied in the field usually adhere to the surface by means of mechanical fixation or Van Der Waals bonding. Other types of bonds rarely exist in practice. Adhesion between hard or semi-hard substances that are used as coatings do not occur in practice. In this case there is always a mechanical fixation: after sandblasting a primer is used to flow into the surface and create "entanglement". Generally, one can say that proper adhesion is not as simple, as it seems; many factors play a role in this process, causing chance of failure.

In general, coatings in the pipeline industry bond to a surface by the following means of mechanical fixation and Van der Waals bonding. In case of mechanical fixation a surface is sandblasted and treated such that a coating can entangle to the surface pattern after drying. This process happens with epoxy, urethane and primer based systems. The distance between the steel surface and the coating is in microns (10^{-6} m). In case of Van Der Waals bonding there s an interaction between the surface and the coating. The bonding is on a molecular level; materials with a low surface tension that are non-drying show Van Der Waals bonding. In this case the VEC's show this adhesion principle. Other examples are petrolatum/wax-based products. The distance between the steel surface and the coating is in Angstroms (10^{-10} m).
In some unique cases, bonding can take place by means of chemical bond, however in this industry, this is not common practice.

With VEC's volume shrinkage is no longer an issue. Moreover, the distance between the coating and the substrate's surface, essential for a perfect adhesion, is extremely small: due to van der Waals bonding, the distance between substrate and coating are as low as 10^{-10} m, not allowing water molecules to find its way between substrate and coating.

When applying a peel test to VEC's, the coating shows an adhesion to the substrate's surface with a cohesive fracture - when peeled off, the material will break apart and a remaining film is left on the pipe.

From a rheological point of view VEC's can be a solid with a high yield point, but retains 'wetting' properties and a low surface tension. On many dry and clean surfaces, the material shows flow under pressure as it acts as a pressure- sensitive adhesive. It flows into the irregularities of the surface and forms a homologue layer of coating. This process may take some time due to the viscous-elastic properties, but will always take place. Pressure, for instance, of an outer wrap or earth loads, will accelerate this process. A very intimate match exists between the substrate and the coating, which results in an extremely good adhesion. Due to the 'wetting' characteristics, adhesion will take place rather quickly and will remain for decades. Due to the use of a 100% inert formulations, the materials will not crack nor become brittle, and will remain plastic.

VEC's should not contain any reactive groups and will not deteriorate in the course of time. VEC's are often protected by an outer wrap for mechanical protection when applied to below ground substrates. In this way, the main function (corrosion prevention) is separated from the mechanical protection, whereas many coatings try to combine both purposes in one material. This is very difficult and usually leads to a sacrifice of one of the functions.

c) Microbiologically influenced corrosion (MIC). MIC is the term used for the phenomenon in which corrosion is initiated or accelerated, or both, by the activities of microorganisms. The first MIC case was discovered in 1934 where sulfate-reducing bacteria (SRB) resulted in the corrosion failure of cast iron pipes.

SRB are obligatory anaerobic bacteria utilizing sulfate as a terminal electron acceptor and organic substances as carbon sources. During the metabolic process, sulfate is reduced to sulfide, which reacts with hydrogen produced by metabolic activities or by cathodic reaction of corrosion processes to form hydrogen sulfide. Hydrogen sulfide is very corrosive to ferrous metals and further reacts with dissolved iron to form an iron sulfide film over the metal substrate. Iron sulfides have relatively low hydrogen evolution over-potential. So a galvanic coupling between iron sulfide film and the nearby metal substrate is set and corrosion is accelerated.

Other important microorganisms are formative acid- producing bacteria (APB) capable of forming organic acids (e.g. acetic, formic and lactic acids). These acids and APB have dual roles in MIC, causing acid corrosion of many alloys and supplying nutrients and environments to the MIC community bacteria.

With VEC's MIC does not occur under the coating. The permanent wet coat wrap consists of an organic polymeric composition with inorganic filler material. It is proposed that if no nitrogen nutrients are available in the coating substance, it is impossible for microorganisms to grow on this material under anaerobic conditions. VEC's are most often water repellent because of its hydrophobic properties and permeation of water is not possible. It is clear: if no water is present, bacterial life is impossible.

MIC does not occur with VEC's because:

- No water is present between metal and coating on a molecular scale.
- No nitrogen is available in the coat wrap.
- No initial bacterial activity is present in the coat wrap.
- The wrap coating molds to the substrate due to the viscous component in the coating.
- There is a real adhesion with no space for any substance to creep between the layer and the substrate.
- The coat wrap is under permanent pressure.
- The coating is impermeable to water and oxygen.
- No permeability for ionic species from soil e.g. nitrate, nitrite and ammonium.
- There is no water available and the ions are insoluble in the a-polar material.
- VEC's are water repellent.
- The material is slightly basic (PH8; unfavorable for SRB).

d) Surface preparation. The Sherwin Williams Company states that as high as 80% of all coating failures can be directly attributed to inadequate surface preparation that affects coating adhesion(3). Very often field-applied coatings need a perfectly prepared surface on the substrate in order to get excellent adhesion, and sandblasting often is required. However, remaining pollutions in the voids of the blasted surface and salt particles create problems, and rapid disbondment may occur. Surface preparation in-plant is relatively easy to control. Surface preparation in the field however is very often difficult to control and requires skill.

VEC's have the ability to adhere to a wide variety of substrate. VEC's do not require the sensitivity to surface preparation that many other coating need. The minimum cleaning requirement is level SP-2. Blasting of the surface is preferred but is not necessary in all circumstances. VEC's have a low glass transition temperature; it can be applied within a wide temperature range, provided it is applied above the dew point. It can be applied at temperatures of -10 °C but also on surfaces with a temperature of +65 °C. Due to the flow under pressure characteristics and the low surface tension, the material shows a perfect adhesion to most materials commonly used in the industry, such as FBE, PE but also PP.

e) Water permeability. Corrosion most always will occur, when coatings do not have sufficient water vapor permeability ratings. The presence of water is deadly for a substrate and no matter how good a coating has been applied in the factory, practice shows that disbondment due to the presence of water occurs. Corrosion is always due to a combination of causes and it cannot be stated that only one of the mentioned phenomena is responsible for corrosion of a substrate itself. However, permeability of water is a factor contributing to many corrosion problems. No matter how well a coating has been applied, no matter how the application circumstances could be controlled, corrosion will occur if water or water vapor is able to travel through a coating, especially if salt particles or pollutions are present in the voids of the blasted substrate. In the case of pipeline rehabilitation, this is an even bigger problem, and the application circumstances that are sometimes difficult to control, should be taken into consideration.

VEC's most often consist of amorphous a-polar polyolefin with no reactive groups or free radicals. They have an extremely low water vapor permeability and are virtually impermeable to moisture under ambient conditions. Due to the absence of free radicals, VEC's remains stable for decades and no deterioration of the material takes place. The coating is amorphous and shows no crystalline behavior. In conjunction with van der Waals forces and permanent wetting properties, it will match the surface of the substrate up to a molecular level. There is no space for moisture due to the extreme close contact on molecular scale of the viscous-elastic coating and the substrate's surface.

Aggressive soils, comparing laboratory results with in the field testing

VEC's are excellent for application in aggressive soils, such as Sabkha areas in the GCC countries and on the Subcontinent. Other areas of application are coastal areas, swampy environment (Louisiana, Texas, Florida), and Muskogee areas in Canada. Laboratory testing predicted this with very low water vapor permeability values and cathodic disbondment values from zero to 3 mm.

Long term field trials were performed in the Sabkha area in the Middle East. This area is known for its high saline and sulphur conditions, constant wet and dry cycling and temperature swings. Many coatings have been tried in the past with many times disappointing results. In this field trial, a section of a 48 inch pipeline was sandblasted SSPC 10 and coated with the viscous elastic system. After 15 months the pipeline was dug up and inspected on visual appearance, peel testing and under creep corrosion. At least two different VEC's systems have been tested this way, both with excellent results, confirming the laboratory data.

Fig. 1 Application of VEC's at a 48 inch pipeline in Sabkha area

Fig. 2 Application of protective outer layer

Fig. 3 Peel tes months: a coh adhesion and excellent coating condition.

Fig. 4 Removal of coating: no corrosion was observed

Conclusions

VEC's easily overcome many of the common issues that cause traditional coating to fail. Viscous elastic coatings offer immediate adhesion without the need for primer, require minimal surface preparation and form a homologue, continuous, self-healing protective layer. The materials bond at an intimate level and create a waterproof, impermeable coating that can operate in a wide temperature range. Viscous elastic chemistry is unique and designed such that the viscous component gives it permanent wetting characteristics. This forces the material to flow into the pores and anomalies of a substrate.

The elastic component of the product gives it the strength and feeling of a solid. Viscous elastic coatings and sealants always remain in a semi-solid state, provide high impact strength and allow for sufficient resistance against shearing. Ease of application and outstanding performance are what make VEC's an excellent technology for corrosion prevention. These products excel in offering corrosion protection for pipelines on areas such as soil to air transitions, flanges, casing, girth welds, field repairs, water proofing of casing end seals and vaults in addition to having numerous other applications.

Product Types

VEC's are available in wrap styles (on a rolls with a release liner), as a paste/mastic, and as a sealant (packaged in a caulk tube). As a paste/mastic it can be used to protect tank bottoms, flanges, valves and irregular spaces. Some can even be used to create waterproof flexible end seals for casings. As a wrap it can be used for the protection of pipelines and larges valves.

Notes

1 Many polymers show viscous elastic behavior. When one measures G' and G" of a VEC coating during dma testing, the value of G" divided by G' is approximately between 0.8 and 1.2.

2 Water Vapor Permeability < 4 $*10^{-4}$ g/day/m2/Pa, ASTM E96/96M-10, Water penetration

<0.14% (1800 hrs, 6V, 3% NaCl), ASTM G9-87, Water absorption 3.7g.m^2 or 0.0013g/g, ASTM D5700-98 (2010)

3 http://protective.sherwin-williams.com/tools/surface-preparation-guide/